Figure 3. When submitted to a pulsed electric field by the phanotron, at polar or kinetochore microtubule resonance frequencies from 100 to 200 kHz, the additional cell surface tension ranges from 1 to 1.3 mN/m for several cancer cells (ovarian, pancreatic, leukemia). The results are obtained with $\Delta t = 1800$ s, $\tau = 0.5$, $A = 0.01$ for equations (4) and (8).

PA-87 [19:00]

Wireless communication and the Precautionary Principle

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Keywords: Public Health Policy, RF/Microwaves, Review, Commentary, Recommendation, Evaluation

The IARC review of the scientific evidence and obtained classification of possible carcinogenicity of cell phone radiation, permit implementation of the Precautionary Principle measures, in order to protect the population from the potentially hazardous effects of exposure to radiation emitted by the wireless communication devices

There is an ongoing debate, whether the Precautionary Principle, as defined by the European Union in 2000, should be implemented to mitigate the possible health risks of exposure to cell phone radiation. In order to consider the use of the PP, the first necessary step is the evaluation of the scientific evidence. In respect to cell phone radiation, this first step was executed in 2011 when the Working group of 30 experts met at the International Agency for Research on Cancer in Lyon, France, and classified cell phone radiation as a possible human carcinogen (Group 2B).

After completion of evaluation of the scientific evidence, there are several pre-conditions that need to be fulfilled before debating the implementation of the PP, in accordance with the EU PP document of 2000. All of these preconditions are fulfilled:

Pre-condition: PP can be implemented when the scientific information is "insufficient, inconclusive, or uncertain"

- IARC classification of cell phone radiation as a possible carcinogen has clearly shown that the information on health effects of cell phone radiation is “insufficient, inconclusive, or uncertain”

Pre-condition: PP can be implemented when "there are indications that the possible effects on human health may be potentially dangerous"

- IARC classification of cell phone radiation, based on the evidence from epidemiological case-control studies, has pointed out that avid long-term cell phone users are at an increased brain cancer risk – this is a potential danger to over 7 billion of cell phone users

Pre-condition: PP can be implemented when "the current situation is inconsistent with the chosen level of protection"

- IARC classification pointing out to an increased brain cancer risk is based on epidemiological studies where subjects used regular cell phones meeting current safety standards; this means that the current safety standards are insufficient to protect users.

Implementation of the Precautionary Principle does not equal prevention of the use of wireless technologies. This policy can help in curbing the current rampant and uncontrolled deployment of wireless networks anywhere and everywhere. The claims that the implementation of the Precautionary Principle will cause economic harm are not justified. Implementation of the Precautionary Principle will create new knowledge through research aimed at resolving the issue of health risk and developing communication technologies with lower radiation emissions. It will, in turn, create new jobs and new economic opportunities in research and technology.

Final conclusion: The IARC review of the scientific evidence and obtained classification of possible carcinogenicity of cell phone radiation, permit implementation of the Precautionary Principle measures, in order to protect the population from the potentially hazardous effects of exposure to radiation emitted by the wireless communication devices. Concomitantly with the implementation of the protective measures, aimed at reduction of exposures of human population, scientific research should continue to resolve the contradictions of the scientific evidence.

PA-89 [19:00]

STUDENT PAPER

SAR_{wb}-meter in diffuse fields, calibrated in a reverberation room

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Keywords: Dosimetry (measurements), RF/Microwaves, Completed (unpublished)

A whole-body absorption meter, calibrated for simultaneous on-body measurements of the incident power density (S_{inc}) and whole-body averaged specific absorption rate (SAR_{wb}) in diffuse fields, is proposed. The meter consists of an on-body, textile antenna tuned to the GSM 900 DL band and is worn by a subject who is exposed to diffuse fields at 942.5 MHz in a reverberation chamber. The set-up allows for measurements of both the subject’s absorption cross section (0.32 m^2), using measurements of the reverberation time, and the antenna aperture (2.8-3.3 cm^2) of an on-body antenna. This antenna can thus be used for a simultaneous on-body measurement of the SAR_{wb} and the S_{inc}.

INTRODUCTION

Personal exposure to radio-frequency (RF) electromagnetic fields (EMFs) is usually measured using personal exposimeters (PEMs) [1, 2]. These are body-worn devices that contain an (on-body) antenna and register (quadratic) electric field strength values in several frequency bands. In order to have a relationship between fields measured by a PEM (on the body) and the incident power density (S_{inc}), these devices have to calibrated on the body [1]. Typically this calibration is carried out in an anechoic chamber [1] or an open-area test site [2]. During these measurements a subject wearing a PEM [2] or an on-body antenna [1] is rotated in the azimuthal plane, in order to emulate a random direction of incidence of the EMFs.

This calibration has two main disadvantages. First, the elevation angle of incident fields is not taken into account, which is problematic for measurements in indoor environments, where a large spread of incident elevation angles is possible [3]. Second, the calibration does not provide any information on the absorption of RF EMFS, commonly quantified using the whole-body averaged specific absorption rate (SAR_{wb}).

In [4], a method is introduced to measure the SAR_{wb} of a human in a reverberation room [5], which is a room designed to create random incident fields. The incident EMFs in a reverberation room are diffuse, meaning that the S_{inc} is uniformly distributed over all incident angles, and thus include a dependence on the elevation angle

The goal of this paper is to calibrate an on-body antenna worn by a human subject in a reverberation chamber. This allows for a calibration that takes into account all incident angles and simultaneously allows for a measurement of the SAR_{wb}. The on-body antenna can then be used as a wearable SAR_{wb}-meter.

MATERIALS AND METHODS

The used RF node consists of a linearly polarized, quarter-wavelength, planar, inverted F-antenna (PIFA) tuned to the Global System for Mobile Communications (GSM) 900 downlink (DL) band: 925-960 MHz, fabricated with textile materials, and an RF power detection unit tuned to the GSM 900 DL band. The RF power detection unit records the received power (P_r) on the textile antenna and provides a geometric averaged received power with a resolution of 1 dB, a sensitivity of -72 dBm, and a sample interval of 1 Hz. The RF node is powered by 3 AA batteries (1.5 V). The RF node is lightweight, does not interfere with body movement, has a surface of 10 x 12 cm², and is suitable for real-life measurements [6].

The absorption of RF EMFs is studied using the absorption cross-section (ACS, unit: m²) in indoor environments. This quantity is defined [3,4] as:

$$ACS = \frac{P_{abs}}{S_{inc}} \qquad (1)$$

with P_{abs} the absorbed power in a room (unit: W) and S_{inc} the incident power density (unit: W/m²) in the diffuse field. This absorption cross section can be obtained from the reverberation time (τ) in a room with volume (V) [3,4].

$$\tau = \frac{V}{ACS \times c} \qquad (2)$$

with c the speed of light.

Figure 1 shows an illustration of the set-up used in the reverberation chamber. The reverberation chamber is a cuboid with a metallic coating of volume V = 5.67 x 4.07 x 2.8 m³ = 65 m³. The room contains an electromagnetic stirrer that can be rotated around its axis and perturbs the EMFs in the reverberation chamber. If the fields in the chamber are averaged over a full rotation of the stirrer, they can be regarded as being perfectly diffuse [5]. The room contains one transmitting antenna (TX), a YAGI antenna, placed on a tripod of 1.5 m height in a corner of the room. The signals are received by an identical receiving antenna (RX) on a tripod of 1.5 m height, which is placed in the opposite corner. The subject, a 26 year old male subject with a BMI of 22 kg/m² and a mass of 81 kg, is placed in four orientations (N(orth),E(ast),S(outh), and W(est)) on positions 1 (pos 1) in the room, see Fig. 1, an in the E direction on pos 2.

First, an isotropic field probe (NARDA NBM 550, Narda, Hauppage, NY, USA) is used to measure the S_{inc} from 0.5 to 2 m above the floor; along a vertical line on each of the two studied positions. During these measurements the TX emits a continuous wave at 942.5 MHz with an input power of 1 mW, while the stirrer rotates 360° at a speed of 3°/s. This S_{inc} is then averaged over the height of the subject (1.91m) and all orientations of the stirrer, in order to determine the S_{inc} in diffuse fields.

Second, the reverberation time τ_0 is measured in an empty room, in order to obtain the ACS_0 of the empty room. In a third step, the human subject is placed in the room and a second reverberation time τ_1 and corresponding ACS_1 is obtained. The ACS_{subj} of the subject is then obtained as the difference between the two reverberation times:

$$ACS_{subj} = ACS_1 - ACS_0 = \frac{V}{c}(\frac{1}{\tau_1} - \frac{1}{\tau_2}) \qquad (3)$$

The ACS_{subj} can be used to determine the SAR_{wb}:

$$SAR_{wb} = \frac{ACS_{subj} \times S_{inc}}{M} \qquad (4)$$

with M the mass of the subject. For these measurements a pulse of 16 µs with a bandwidth of 100 MHz around 942.5 MHz (pos 1) or 953 MHz (pos 2) is used. The value measured on pos 2 only serves as a validation of the one measured on pos 1.

In a fourth step, the subject is equipped with an RF node, which is placed horizontally polarized (parallel to the floor) on the subject's left chest. The TX emits at 942.5 MHz at an input power of 1 mW and the stirrer is rotated at a speed of 3°/s from 0° to 360°, emulating a diffuse field. During this rotation, the received power on the antenna (P_r) is recorded as a function of the rotation angle φ of the stirrer. These are then averaged over φ, in order to obtain the received power on the antenna in diffuse fields. The antenna aperture (AA) in diffuse fields is then equal to:

$$AA = \frac{P_r}{S_{inc}} \qquad (5)$$

This AA can be used to determine the SAR_{wb} from measurements with the RF nodes in diffuse fields:

$$SAR_{wb} = \frac{ACS_{subj} \times S_{inc}}{M} = \frac{ACS_{subj} \times P_r}{M \times AA} = \frac{P_r}{MF} \qquad (6)$$

with MF the mass factor (unit: kg). This is the factor that can be used to obtain the SAR_{wb} from the power received on an antenna. The AA and the ACS_{subj} should be independent of the subject's position and orientation in the reverberation chamber.

RESULTS

	Position 1	Position 2
ACS_{subj} (m^2)	0.32 [0.29,0.35][a] (@ 942.5 MHz)	0.34 [0.31,0.37][a] (@ 953 MHz)
S_{inc} (mW/m^2)	3.0 [2.3,3.9][a]	3.4 [2.7,4.2][a]
P_r (μW)	1.0 [0.34,3.0][a]	0.94 [0.42,2.1][a]
AA (cm^2)	3.3 [1.1,10][b]	2.8 [1.2,6.3][b]
MF (kg)	0.084 [0.028,0.25][c]	0.071 [0.031,0.16][c]

[a] Logarithmic mean and 68% confidence interval
[b] Logarithmic mean and combined 68% confidence interval
[c] Logarithmic mean and combined 68% confidence interval, calculated with an ACS = 0.32 m^2
ACS =Absorption Cross Section, S_{inc} = incident power density, P_r = received power,
AA= Antenna Aperture, MF = Mass Factor

Table 1: Results of calibration measurements.

Table 1 lists the different measured ACS values, determined using the measurements of τ_0 and τ_1. The measured ACS values, which are 0.32 m² at 942.5 MHz and 0.34 m² 953 MHz, on positions 1 and 2, respectively, are comparable for both measured positions and have a relative small 68% confidence interval of 0.8 dB (0.06 m²). This value can be used to estimate the SAR_{wb} of the subject in diffuse fields. For example, for a diffuse S_{inc} = 1 W/m², the SAR_{wb} of the subject would be 0.004 W/kg. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) reference level at 942.5 MHz is 4.7 W/m² [7], which would correspond to a SAR_{wb} of 0.019 W/kg, which is lower than the basic restriction of 0.08 W/kg.

The mean AA of the antenna placed on the left chest is 3.3 cm² on position 1 and 2.8 cm² on position 2, see Table 1. The confidence interval on the mean value is determined using a combined standard uncertainty calculated using the measured standard uncertainties on P_r and S_{inc}. The two measured AA values are similar and show overlapping confidence intervals. In diffuse fields, the AA of the same antenna should be the same, regardless the orientation or position in the diffuse fields [3]. The AA can be used to estimate the S_{inc} from measurement of the on body antenna. In a diffuse environment, a P_r of 1 W on the antenna corresponds to a mean S_{inc} of 3 mW/m², using the AA of 3.3 cm², measured on pos 1, see Table 1. The on-body antenna can thus serve as a PEM for diffuse (indoor) environments.

The most important advantage of this calibration method is that it allows for the determination of the MF, without using any numerical simulations. Table 1 lists MF values of 0.084 and 0.067 kg, measured on pos 1 and 2, respectively. This MF enables one to directly estimate the SAR_{wb} of the subject in diffuse environments, from on-body measurements. When using the average MF=0.076 kg, a received power of 1 mW on the antenna corresponds to a mean SAR_{wb} of 0.013 W/kg. In [6], a MF of 0.11 kg is estimated for a set of RF nodes tuned to the same frequency band, worn on the body in a specular environment. This value is higher than the values presented in Table 1, potentially due to the difference polarization distributions (uniform in diffuse and normal in the studied specular environment) and the absence of elevation angles in the calibration measurements in [6], but lies within the 68% confidence intervals listed in Table 1.

CONCLUSIONS

We propose a whole-body absorption meter, calibrated for simultaneous on-body measurements of the incident power density (S_{inc}) and whole-body averaged specific absorption rate (SAR_{wb}) in diffuse fields, using an on-body textile antenna. An on-body, textile antenna tuned to the Global System for Mobile (GSM) communications downlink band around 900 MHz is worn on the body of a subject who is exposed to diffuse fields at 942.5 MHz in a reverberation chamber. The subject has an absorption cross section of 0.32 m^2, which is determined using measurements of the reverberation time. The antenna aperture of an on-body antenna and the S_{inc} can be measured using the same setup. This allows for a simultaneous estimation of the SAR_{wb} and the S_{inc} from measurements on the body. The advantages of this technique are that it does not require any numerical simulations, and corresponding simulation uncertainties, and that all incident angles for the S_{inc} are included.

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Figures

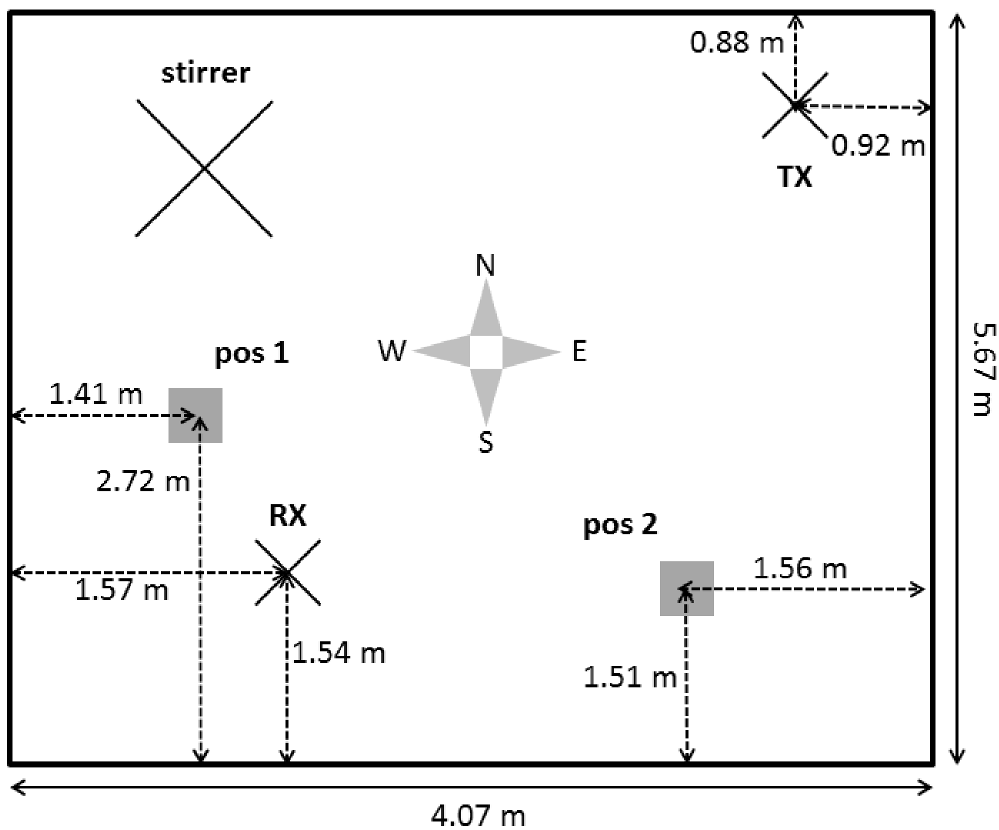

Figure 1. Top view of the measurement set-up in the reverberation chamber (not to scale). The measurement positions (pos 1 and 2) are indicated by grey squares.

PA-91 [19:00]
STUDENT PAPER

Calcium-independent disruption of microtubule growth following nanosecond pulsed electric field exposure in U87 human glioblastoma cells

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Keywords: In vitro, Pulsed, Work in Progress

Nanosecond pulsed electric field (nsPEF) exposure causes apoptosis in cancer cells via a currently unknown mechanism. We used live cell imaging to show that 100, 10 ns, 15 kV/cm pulses, applied at 10 Hz to U87 EB3-GFP glioblastoma cells, results in calcium-independent disruption of microtubule growth. Microtubule depolymerization is a key event in apoptosis execution, making the effect we report on the microtubule network a candidate for the mechanism behind nsPEF induced apoptosis.

Introduction

High powered, nanosecond duration pulsed electric fields (nsPEF) have been proposed as a minimal side-effect, electrical cancer therapy that is unlikely to result in resistance. In vitro and in vivo studies have demonstrated that nsPEF are able to induce apoptotic death in cancerous cells and reduce tumor size [1,2]. However, the mechanism of how nsPEF triggers apoptosis remains unknown.

Microtubules form part of the cell cytoskeleton and their depolymerization is an intrinsic, early event in normally occurring apoptosis[3]. Electric fields have been shown to disrupt microtubule polymerization[4,5]. Given this, it is therefore possible that nsPEF cause microtubule depolymerization which initiates apoptosis.

In this study we follow the microtubule plus end tracking protein EB3-GFP with live cell imaging to visualize microtubule growth dynamics in U87 glioblastoma cells. We demonstrate that 100, 10ns pulses delivered at a frequency of 10 Hz cause a rapid disruption of microtubule growth. We also show that this effect is not dependent on influx or release of calcium, a

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